

Europäisches Patentamt
European Patent Office
Office européen des brevets



(11) EP 1 180 869 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
20.02.2002 Bulletin 2002/08

(51) Int Cl.7: H04L 1/18

(21) Application number: 01118870.3

(22) Date of filing: 16.08.2001

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

• FUJITSU LIMITED
Kawasaki-shi, Kanagawa 211-8588 (JP)

(72) Inventor: Niu, Zhisheng
Haidian District, Beijing 100084 (CN)

(30) Priority: 18.08.2000 CN 00123517

(74) Representative: HOFFMANN - EITLE
Patent- und Rechtsanwälte Arabellastrasse 4
81925 München (DE)

(71) Applicants:
• TSINGHUA UNIVERSITY
Beijing100084 (CN)

(54) A TCP aware local retransmission scheme for unreliable transmission network

(57) The present invention relates to a local retransmission scheme, which uses Transport Control Protocol (TCP) in an unreliable network. It provides reliable transmission for out-of-order TCP data packet in unreliable link. It recovers all non-congestion loss packets. It avoids incorrect adjustment of window size in TCP source end. It applies a TCP local retransmission scheme, which checks together link layer transfer se-

quence and TCP source delivery sequence. With inserting timestamp of local sequence number, which is in TCP data packet and TCP acknowledgement packet, together with acknowledgement number AN, it is defined whether a data packet is lost and retransmitted. Then, with explicit retransmission ERN feedback, a TCP source false action is avoided. Therefore the TCP performance of wireless network is greatly improved.

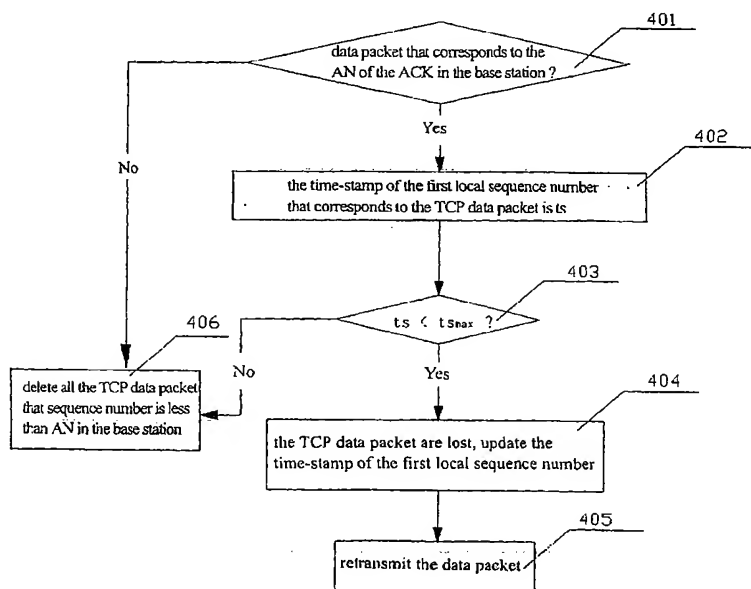


Figure 4:

Description

[0001] Present invention relates to a retransmission scheme on unreliable network. More precisely, it concerns one kind of TCP Aware Local Retransmission scheme for Transport Control Protocol (TCP). The scheme provides reliable retransmission on unreliable transmission link and avoids effectively the disturbance between different layers of protocol, so it improves greatly TCP performance of the unreliable network.

[0002] With the rapid development of Internet, it is very possible to be the united platform of multimedia networks in the future. Therefore, it is very important to access Internet with various network technologies, among them accessing through mobile communication system to Internet is more real. ITU is now making great efforts to promote international standards of the third generation mobile communication system (IMT2000), which is expected to support mobile computing and nomadic access of Internet. It could be said, with the development of network technology and business, the lower layers of Internet is more and more varieties. It was unpredictable for the Internet creators that the simple assumptions of the network characteristic at the creation beginning stage cause many of its kernel protocols are not adequate to the varieties of mixed network in the future, especially for the TCP layer.

[0003] TCP is originally designed for wire link networks and has been widely used in Internet. It provides reliable transport service for applications, such as WWW browsing, remote login (Telnet) and file transfer (FTP) etc. But many of the basic technologies, which the protocol is based on, are unreliable from the present point of view. For example, all of the packet losses are regarded as the result of congestion.

[0004] Generally speaking, TCP performance is guaranteed by the technical schemes: the congestion control and error recovery. The congestion control is based on the sliding window scheme, which has been improved repeatedly and is nearly perfect. The basic idea of error recovery is the feedback of acknowledgement, with the transfer of limited feedback information, i.e. the ACK (acknowledge) and NACK (non-acknowledge), to decide whether to retransmit the data packet. But it cannot differentiate the congestion loss and non-congestion loss by itself. This means in spite of loss is congestion or non-congestion, the TCP source inflates window size automatically when ACK received, and shrinks automatically when NACK received. In this way the window size is adjusted to the network volume (throughput) in order to decrease the possibility of congestion. In practice of transmission processes especially in the unreliable network such as wireless link, because the error rate is higher at the wireless environment and non-congestion loss is severe at bad channel, this is an incorrect trigger of congestion control. This incorrect control causes unnecessary adjustment of window size, it decreases availability of network resources. At the same time as

the window is severely disturbance, TCP performance is worse. Therefore, TCP is facing many challenges in unreliable network such as wireless network.

[0005] On the other hand, the TCP recovery ability of losing packet is limited. There are many improving proposals for increasing the packet retransmission rate and efficiency, such as TCP-New Reno(Reference [1] J. C. Hoe, Improving the Start-Up Behavior of a Congestion Control Scheme for TCP. In proceeding ACM SIGCOMM 96, August 1996) and TCP-SACK (Reference [2] Fall and S. Floyd, Simulation-based Comparisons of Tahoe, Reno and Sack TCP, Computer Communication Review, July 1996). All of these proposals do not solve the difficult problem that is to identify the reason of losses. If using the Explicit Loss Notification (ELN) bit to solve this problem (Reference [3] Harl, Balakrishnan, and Randy H. Katz, Explicit Loss Notification and Wireless Web Performance, Globecom 98, Sydney, Australia, November 1998), it needs to update the kernel protocol of Internet, so it is infeasible.

[0006] In summary, a mixed network, especially with wireless networks, the urgent problem to be solved is to differentiate the congestion loss packet and non-congestion loss packet, and to solve the incorrect window size adjustment when non-congestion loss packet is detected.

[0007] In order to solve these problems, some local solutions have been proposed, such as based on link-layer AIRMAIL (Reference [4] E. Ayanoglu, S. Paul, T. F. Laporta, K. K. Sabnaai and R. D. Gitlin, AIRMAIL: A Link-Layer protocol for Wireless Network. ACM ACM/Baltzer Wireless Networks Journal, 1: 47-60, February 1995) and other ARQ/FEC (Automatic retransmission request. Forward error correction). With retransmission of the lost packet, they improve TCP performance, but with these pure local solutions, a large amount of overhead is added and decreases the efficiency. Reference [5] (H. Balakrishnan, S. Seshan and R. H. Katz, Improving Reliable Transport and Handoff Performance in Cellular Wireless Networks, ACM Wireless Networks, December 1995) proposes the awareness concept to solve this problem. This concept applies TCP/ACK (Transmission Control Protocol/Acknowledgement) packet in link layer to provide the local retransmission. Because it still uses the timer for lost packet recovery, it is necessary to estimate the round-trip time accurately. Besides, with timer in base station, a lot of system resource is wasted. At TCP source side to prevent ACK duplication, unnecessary timeout cannot be avoided totally.

[0008] Congestion or Retransmission causes the packets out-of-order. If an out-of-order packet is lost at wireless link, it is impossible to recover it with duplicated ACK or partial ACK. A current solution is the timeout retransmission, it is needed to estimate the round-trip time accurately in a wireless link, but it is difficult to do for an unreliable wireless network.

[0009] Another solution is to use a pure link layer protocol, such as automatic retransmission request (ARQ).

In this solution, the protocol can give every packet a sequence number to identify the arrival order and to use it for recovery of losses, but the overhead will cause lower efficiency.

[0010] The purpose of this invention is to design a local retransmission scheme by using TCP in unreliable network to solve the loss of out-of-order packets, by differentiating congestion loss and non-congestion loss to avoid the false actions of TCP source. With all these effort to get a better TCP performance in an unreliable link.

[0011] This invention uses a technical scheme with cooperation of transport and link layer. That is TCP Aware Local Retransmission. It uses link layer transmission sequence together with TCP source delivery sequence to detect the lost data packet, then using Explicit Retransmission Notification (ERN) to avoid the false actions of TCP source. The invention is based on the TCP aware local retransmission.

[0012] The invention is implemented as follows: a local retransmission mechanism of TCP used in unreliable network, is characterized in the following steps:

A. When the access point of unreliable link receives a new TCP data packet from Internet TCP source, it inserts the packet a LAC-PDU head with time-stamp of first local sequence number. The packet is encapsulated to a LAC-PDU packet as "LAC-PDU head + IP head + TCP head + Data", then is delivered to the current terminal;

B. When the current terminal successfully receives a TCP data packet, it produces an acknowledgement packet (ACK1) which includes an acknowledgement number (AN). It is also inserted a LAC-PDU head with time-stamp of second local sequence number, i.e. the acknowledgement packet is encapsulated to a LAC-PDU acknowledgement packet and is delivered back to the access point of unreliable link;

C. At the access point of unreliable link, a detection of whether there is a data packet loss is made. This is according to the Acknowledgement Number (AN), the Time-stamp of second local sequence number, both received from the acknowledgement package, and the Time-stamp of first local sequence number, which is stored in the access point. If a lost data packet is detected, as step A procedure, updates its time-stamp of first local sequence number in LAC-PDU head, and retransmits. When congestion loss of the data packet is impossible, which corresponds to the acknowledgement number (AN) of acknowledgement packet, the acknowledgement packet (ACK1), with explicit retransmission feedback (ERN) field marked, is delivered to the TCP source.

[0013] In step A mentioned above, when a LAC-PDU head with time-stamp of first local sequence number is inserted, a copy of the encapsulated LAC-PDU data

packet is stored in a buffer at the same time.

[0014] The time-stamp of first local sequence number, mentioned above, is a fix length bit field. Along with delivered data packet increases, starting from 0 with 1 as step length its value increases sequentially.

[0015] During the whole delivery process from access point to terminal, the real delivery sequence is uniquely determined by the time-stamp value of first local sequence number in TCP data packet.

[0016] The time-stamp of second local sequence number, mentioned above, is also a fix length bit field. It records the maximum value of time-stamp of first local sequence number among all the successfully received TCP data packets in current terminal.

[0017] As mention above at access point of unreliable link, a lost data packet is detected according to the acknowledgement number (AN), the time-stamp of second local sequence number, both comes from received acknowledgement packet, and the time-stamp of first local sequence number, which is stored at the access point. Further more, detection is made for whether the data packet is still in the access point of unreliable link,, which corresponds to the acknowledgement number (AN) of acknowledgement packet, if it is, a comparison between two time-stamps is made. The comparison is between the time-stamp of first local sequence number in the data packet and the time-stamp of second local sequence number in the acknowledgement packet. If the time-stamp of first local sequence number is less than the time-stamp of second local sequence number, the lost data packet is detected; then the time-stamp of first local sequence number at the LAC-PDU head is updated and the data packet is retransmitted. In addition, in the access point of unreliable link, the data packets, which time-stamp of first local sequence number is less than the acknowledgement number (AN), are all deleted.

[0018] The update of the time-stamp of first local sequence number at the LAC-PDU head of the data packet, mentioned above, substitutes the time-stamp of first local sequence number with the current delivery sequence, then retransmits.

[0019] As mentioned above, in the access point of unreliable link, the data packets, which TCP sequence number is less than the acknowledgement number, are all deleted at the following situations. They are:

a data packet, which corresponds to acknowledgement number (AN) of acknowledgement packet, is not in the access point of unreliable link;;
the time-stamp of first local sequence number is equal or greater than time-stamp of second local sequence number;
after data packet is lost, updated and retransmitted.

[0020] The explicit retransmission (ERN) feedback, mentioned above, is an one bit field. When the data packet, corresponding to the acknowledgement number (AN), is in the access point of unreliable link, the explicit

retransmission (ERN) feedback bit of acknowledgement packet (ACK1), which is to be sent to TCP source, is set. When TCP source receives an acknowledgement packet (ACK1) with explicit retransmission (ERN) feedback bit set, at the same time fast retransmission or timeout retransmission of the TCP data packet happen, which corresponds to the acknowledgement packet (ACK1), only the data packet is retransmitted without any shrink operation of the sending window.

[0021] The mentioned above time-stamp length, for first local sequence number or second local sequence number, is the maximum packet number can be buffered at the access point of unreliable link.

[0022] The mentioned above time-stamp length, for first local sequence or second local sequence number, is an eight bits field, including one carry bit for overflow.

[0023] In mentioned step A, in LAC-PDU data packet the time-stamp of first local sequence number may be substituted by lower layer transfer sequence number, and a corresponding relationship between sequence number of TCP data packet and its lower layer transfer sequence number is created. With this substitution, in mentioned step B, the time-stamp of second local sequence number is the successfully received maximum transfer sequence number of lower layer in the terminal.

[0024] The invention, A TCP local retransmission scheme, used in unreliable network, the characteristic is as follows : Method of transmitting a data packet for Mobile communication system which receives the data packet including sequence number from Internet Networks and transmits the data packet to mobile terminal ; said transmitting method comprising the steps of:

receiving a new data packet from Internet Network ;
giving a time-stamp of first local sequence number to the each received data packet;
forming the packet data to a format using in the mobile communication system with the given time-stamp of first local sequence number ;
buffering the packet data with the time-stamp ;
transmitting the formed packet data to the mobile terminal sending back a acknowledgement data from the mobile terminal ; when the mobile terminal successfully receives the transmitted packet data , which includes an acknowledgement number and the time-stamp of second local sequence number corresponding to the received time-stamp of first local sequence number;
detecting the data packet which should be retransmitted to the mobile terminal by comparing the buffered sequence number and the time-stamp of first sequence number with the sent back acknowledgement data ; and
retransmitting the detected data packet .

[0025] Method of transmitting a data packet, wherein said mobile communication system includes a server , said server gives the time-stamp of first local sequence

number to the each received data packet, forms the packet data to the format using in the mobile communication system with the time-stamp of first local sequence number and buffers the packet data with the time stamp .

[0026] The invention, A TCP local retransmission scheme, used in unreliable network, the characteristic is as follows : Method of receiving data packet of Mobile terminal in Mobile communication system which receives data packet including sequence number from Internet Networks and transmits the data packet to the mobile terminal ; said receiving method comprising the steps of:

receiving a new data packet which is formed to a format using in the mobile communication system , the formed the data packet includes a time-stamp of first local sequence number;
giving a time-stamp of second local sequence number corresponding to the received time-stamp of first local sequence number;
sending back a acknowledgement data which includes an acknowledgement number and the given time-stamp of second local sequence number corresponding to the received time-stamp of first local sequence number.

[0027] The invention points to user terminal environment, such as mobile terminal. With unreliable link, such as wireless link, it is connected to data network, such as Internet, and an one direction TCP connection from remote server to wireless access point then to mobile terminal is established. The invention solves non-congestion loss problem of the out-of-order TCP data packet in the unreliable link with the following ideas. The time-stamp of first local sequence number is used to identify the real transmitting sequence of TCP data packets in the unreliable link segment. Then with the acknowledgement number (AN) of TCP acknowledgement packet and the corresponding first and second local sequence number, the lost data packet, which corresponds to the acknowledgement number (AN), is detected. If it is lost, the data packet is retransmitted locally. At the same time, with explicit retransmission (ERN) feedback, false window action is prevented. Therefore, the invention is one kind of cooperation, between time-stamp of local sequence number and acknowledgement number (AN), to detect the lost data packet, and it is also an explicit retransmission feedback method.

[0028] The advantages of this invention are as following. Because the lost data packet is detected by the cooperation of TCP acknowledgement packet (ACK1) and local sequence number time-stamp, and it is retransmitted locally, so without the lower layer extra overhead for control, the non-congestion loss of data packet is recovery by retransmission in time. It has characteristics of fast recovery and high efficiency. It recovers out-of-order TCP lost data packet effectively.

[0029] With the appended figures, the invention is further explained in the following.

[0030] Figure 1 is the structure diagram of one direction TCP connection in a mixed network with wireless access.

[0031] Figure 2 is the structure diagram of data packet transmission from wireless access point to mobile terminal.

[0032] Figure 3 is the corresponding relationship diagram between TCP sequence number and time-stamp of first local sequence number.

[0033] Figure 4 is the flowchart diagram using acknowledgement packet (ACK1) to detect data packet loss.

[0034] Reference to figure 1, a mixed network with wireless access, for example mobile communication system based on IMT2000, is shown. 10 is the international interconnection network (Internet Network), 20 is a remote server, i.e. TCP source, of Internet, 30 is a wireless (unreliable link) access point server, 40 is a mobile terminal (also a mobile computer, user terminal or user computer). The wireless access server is in a mobile communication system which comprises a Mobile Exchanger, Radio Network Controller and base station. The wireless access server can be set up in the Mobile Exchanger, Radio Network Controller or base station. Further, function of wireless access server can be installed to the Mobile Exchanger, Radio Network Controller or base station without setting up the wireless access server.

[0035] The operation of wireless access point server 30 is as following. When it receives a new TCP data packet which comes from TCP source 20 in Internet 10, it encapsulates the data packet in a Link Access Control Protocol Data Units (LAC-PDU). There is a fix length bit field in the LAC-PDU head for each LAC-PDU data packet. This field is used to record the real transmission sequence number, i.e. delivery sequence, and is referred to as time-stamp of first local sequence number. The structure of the LAC-PDU data packet is shown in figure 2. It is "LAC-PDU head (with time-stamp of first local sequence number) + IP head + TCP head + DATA". When the time-stamp of first local sequence number is filled in, the LAC-PDU data packet is also copied to the buffer at the same time.

[0036] As data packets increase, the time-stamp value of first local sequence number is increased with the step of 1, starting from 0. Therefore each TCP data packet moves from wireless access point server (base station) 30 to mobile terminal 40, its real transmitting sequence is uniquely defined by the time-stamp of first local sequence number in LAC-PDU data packet. As shown in figure 3, #1, #2, #4, #3 ... represent TCP data packet sequence number, 0, 1, 2, 3 ... represent time-stamp value of first local sequence number corresponding to LAC-PDU data packet #1, #2, #4, #3 ... respectively. They are delivered along the time axis t sequentially. In the international interconnection (i.e. Internet) or

large scale local area network (i.e. WAN: wide area network), there are many paths to connect between a data source and end user for realize a reliable network. This means that if the first established path has a network congestion, the system may choose another path to deliver data. However, each path has a different delivery time. Thus, during a data transfer, a path change caused out-of-order data delivery. As a result, there is a case that the wireless access server receives TCP packet data by above order of #1, #2, #4, #3

[0037] Mobile terminal 40 produces an acknowledgement packet (ACK1) for each successfully received TCP data packet. As the TCP data packet, the acknowledgement packet is also encapsulated in a LAC-PDU. At the head of this LAC-PDU packet, there is a field for time-stamp of second local sequence number. This field records the maximum time-stamp value of first local sequence number for all successfully received TCP data packet. The current mobile terminal sends back to wireless access point server (base station) 30 acknowledgement packet (ACK1), with the time-stamp of second local sequence number and acknowledgement number. It is used to detect TCP data packet loss at wireless link. The detection method is further described by reference to figure 4. Said Acknowledgment number means a number that indicates the next sequence number expected. In a backhanded manner, this also shows the TCP sequence number of the continuously received last TCP data packet; it shows TCP sequence number of the continuously received last TCP packet data plus 1.

[0038] Step 401 detects whether there is a TCP data packet, which sequence number corresponds to the acknowledgement number (AN) of acknowledgement packet (ACK1), in the buffer of wireless access point server 30 (base station). If it is then executes step 402, otherwise step 406. Step 402 gets the time-stamp of first local sequence number in the TCP data packet, said ts . Step 403 compares ts with the time-stamp of second local sequence number, said ts_{max} , carried by the acknowledgement packet, to detect whether there is $ts < ts_{max}$. If it is $ts < ts_{max}$, then executes step 404, 405 and 406, otherwise step 406. When $ts < ts_{max}$, step 404 and 405 are executed. It means the TCP data packet, corresponding to acknowledged data packet sequence number (AN), is lost. Then substituting the time-stamp of first local sequence number, the TCP data packet is retransmitted. This means a new time-stamp, which represents current transmitting sequence number, substitutes the time-stamp of first local sequence number of the LAC-PDU data packet, which corresponds to the acknowledgement number (AN), then the updated LAC-PDU data packet is retransmitted. Step 406 deletes all the TCP data packet, which sequence number is less than AN, in the wireless access point server (base station) 30, under the following situations. They are: there isn't a TCP data packet corresponding to acknowledged data packet sequence number (AN) in acknowledgement packet (ACK1), in the buffer of wireless

access point server (base station) 30; there isn't $ts < ts_{max}$ and after step 404 and 405 are executed.

[0039] In the invention, an explicit retransmission (ERN) feedback (or explicit retransmission notification) bit is defined in the unused bits (as 6 bits) of acknowledgement packet (ACK1) head. When there is a TCP data packet, corresponding to the acknowledged data packet sequence number in the acknowledgement packet, in the buffer of wireless access point server (base station) 30, the explicit retransmission (ERN) feedback bit in this acknowledgement packet is set. The acknowledgement packet (ACK1), which includes the explicit retransmission (ERN) feedback and the acknowledged data packet sequence number AN, is sent to TCP source 20. When TCP source 20 receives an acknowledgement packet with explicit retransmission (ERN) feedback bit set, and the TCP data packet, corresponding to the acknowledgement packet (ACK1), is in the fast retransmission or timeout retransmission, there are no any operation to shrink the window size, only the TCP data packet is retransmitted.

[0040] The time-stamp value of first or second local sequence number is fix. Its length is the possible maximum buffered data packets for a TCP connection in the wireless access point (base station). If a TCP data packet length is 576 bytes, time-stamp of local sequence number takes value 0 - 127 (in general, it is enough for a TCP connection), i.e. time-stamp length of sequence number is 7 bits.

[0041] As transmitted data packet number increases, when the time-stamp value of local sequence number exceeds its possible represented maximum value, an overflow happens and it is counted starting from 0 again. In this case, the time-stamp of local sequence number cannot represent the real data packet sequence number, so there is a carry bit in this invention. When overflow happens, the carry bit is complemented. In this way at step 403, a correct checking for greater and less relation of two time-stamps of local sequence number can be made, so an 8 bits length of time-stamp for local sequence number is suggested.

[0042] In the invention, a time-stamp of local sequence number is used to identify real sequence number of TCP data packet transmitted on an unreliable link, so any other equivalent manners can be employed, if it implements the function.

[0043] The implementation of this invention encapsulates TCP data packet and time-stamp of local sequence number together in LAC-PDU, then transmits. In many mobile communication system, they provide transfer function of transmitting sequence number in lower layer (data link layer). In this case the detection of data packet loss can be performed under the following conditions. They are: corresponding relationship between sequence number of TCP data packet and transmitting sequence number of its lower layer is established; the mobile terminal sends back to base station the lower layer maximum transmitting sequence

number it receives. In practice, the lower layer transmitting sequence number acts the function of time-stamp of local sequence number.

[0044] The invention can be widely used in many reliable data communication which access data network - Internet with unreliable link.

[0045] The key idea of this technical scheme is combining the advantages of TCP and Data Link layer, in order to decrease the data link layer overhead and provide effective reliable transmission for out-of-order packet. In our scheme, the time-stamp, which can be seen as sequence number of data link layer for the TCP section, represents the TCP section transmitting sequence in the unreliable link access point.

[0046] With simulation, our conclusion is as follows. The technical scheme of this invention definitely and greatly improves TCP performance of unreliable network, such as wireless network.

Claims

1. A TCP local retransmission method, used in unreliable network, **characterized by** the following steps:

A. When the access point of unreliable link receives a new TCP data packet from Internet TCP source, it inserts the packet a LAC-PDU head with time-stamp of first local sequence number. The packet is encapsulated to a LAC-PDU packet as "LAC-PDU head + IP head + TCP head + Data", then is delivered to the current terminal;

B. When the current terminal successfully receives a TCP data packet, it produces an acknowledgement packet (ACK1) which includes an acknowledgement number(AN). It is also inserted a LAC-PDU head with time-stamp of second local sequence number, i.e. the acknowledgement packet is encapsulated to a LAC-PDU acknowledgement packet and is delivered back to the access point of unreliable link;

C. At the access point of unreliable link, a detection of whether there is a data packet loss is made. This is according to the Acknowledgement Number (AN), the Timestamp of second local sequence number, both received from the acknowledgement package, and the Timestamp of first local sequence number, which is stored in the access point. If a lost data packet is detected, as step A procedure, updates its timestamp of first local sequence number in LAC-PDU head, and retransmits. When congestion loss of the data packet is impossible, which corresponds to the acknowledgement number (AN) of acknowledgement packet, the

acknowledgment packet (ACK1), with explicit retransmission feedback (ERN) field marked, is delivered to the TCP source.

2. The method according to claim 1, **characterized by** the following steps. In step A mentioned above, when a LAC-PDU head with time-stamp of first local sequence number is inserted, a copy of the encapsulated LAC-PDU data packet is stored in a buffer at the same time. 5
3. The method according to claim 1 or 2, **characterized in that** the time-stamp of first local sequence number, mentioned above, is a fix length bit field. Along with delivered data packet increases, starting from 0 with 1 as step length its value increases sequentially. 15
4. The method according to claim 1 or 2, **characterized in that** during the whole delivery process from access point to terminal, the real delivery sequence is uniquely determined by the time-stamp value of first local sequence number in TCP data packet. 20
5. The method according to claim 1 or 2, **characterized in that** the time-stamp of second local sequence number, mentioned above, is also a fix length bit field. It records the maximum value of time-stamp of first local sequence number among all the successfully received TCP data packets in the current terminal. 25
6. The method according to claim 1 or 2, **characterized in that**, as mentioned above at access point of unreliable link, a lost data packet is detected according to the acknowledgement number (AN), the time-stamp of second local sequence number, both comes from received acknowledgement packet, and the time-stamp of first local sequence number, which is stored at the access point. Further more, detection is made for whether the data packet, which corresponds to the acknowledgement number (AN) of acknowledgement packet, is still in the access point of unreliable link, if it is, a comparison between two time-stamps is made. The comparison is between the time-stamp of first local sequence number in the data packet and the time-stamp of second local sequence number in the acknowledgement packet. If the time-stamp of first local sequence number is less than the time-stamp of second local sequence number, the lost data packet is detected; then the time-stamp of first local sequence number at the LAC-PDU head is updated and the data packet is retransmitted. In addition, in the access point of unreliable link, the data packets, which time-stamp of first local sequence number is less than the acknowledgement number (AN), are all deleted. 30
35
40
45
50
55

7. The method according to claim 6, **characterized in that** the update of the time-stamp of first local sequence number at the LAC-PDU head of the data packet, mentioned above, substitutes the time-stamp of first local sequence number with the current delivery sequence, then retransmits.
8. The method according to claim 6, **characterized in that**, as mentioned above, in the access point of unreliable link, the data packets, which TCP sequence number is less than the acknowledgement number, are all deleted at the following situations. They are:
 - a data packet, which corresponds to acknowledgement number (AN) of acknowledgement packet, is not in the access point of unreliable link;
 - the time-stamp of first local sequence number is equal or greater than the time-stamp of second local sequence number;
 - after lost data packet is detected, updated and retransmitted.
9. The method according to claim 6, **characterized in that** the explicit retransmission (ERN) feedback, mentioned above, is a one bit field. When the data packet, corresponding to the acknowledgement number (AN), in the access point of unreliable link is detected, the explicit retransmission (ERN) feedback bit of acknowledgement packet (ACK1), which is to be sent to TCP source, is set. When TCP source receives an acknowledgement packet (ACK1) with explicit retransmission (ERN) feedback bit set, at the same time fast retransmission or timeout retransmission of the TCP data packet happen, which corresponds to the acknowledgement packet (ACK1), only the data packet is retransmitted without any shrink operation of the sending window.
10. The method according to claim 1, **characterized in that** the mentioned above time-stamp length, for first local sequence number or second local sequence number, is the maximum packet number can be buffered at the access point of unreliable link.
11. The method according to claim 1, **characterized in that** the mentioned above time-stamp length, for first local sequence or second local sequence number, is an eight bits field, including one carry bit for overflow.
12. The method according to claim 1, **characterized in that** in mentioned step A, in LAC-PDU data packet the time-stamp of first local sequence number may be substituted by lower layer transfer sequence number, and a corresponding relationship between

sequence number of TCP data packet and its lower layer transfer sequence number is created. With this substitution, in mentioned step B, the time-stamp of second local sequence number is the successfully received maximum transfer sequence number of lower layer in the terminal. 5

13. A TCP local retransmission method, used in unreliable network, **characterized by:** A method of transmitting a data packet for Mobile communication system which receives the data packet including sequence number from Internet Networks and transmits the data packet to mobile terminal ;said transmitting method comprising the steps of: 10

receiving a new data packet from Internet Network; 15
giving a time-stamp of first local sequence number to the each received data packet;
forming the packet data to a format using in the mobile communication system with the given time-stamp of first local sequence number; 20
buffering the packet data with the time-stamp;
transmitting the formed packet data to the mobile terminal sending back a acknowledgement data from the mobile terminal , when the mobile terminal successfully receives the transmitted packet data , which includes an acknowledgement number and the time-stamp of second local sequence number corresponding to the received time-stamp of first local sequence number; 25
detecting the data packet which should be retransmitted to the mobile terminal by comparing the buffered sequence number and the time-stamp of first sequence number with the sent back acknowledgement data; and 30
retransmitting the detected data packet. 35

14. The method according to claim 13, **characterized by** a method of transmitting a data packet, wherein said mobile communication system includes a server, said server gives the time-stamp of first local sequence number to the each received data packet , forms the packet data to the format using in the mobile communication system with the time-stamp of first local sequence number and buffers the packet data with the time stamp . 40 45

15. A TCP local retransmission method, used in unreliable network, **characterized by** a method of receiving data packet of Mobile terminal in Mobile communication system which receives data packet including sequence number from Internet Networks and transmits the data packet to the mobile terminal; said receiving method comprising the steps of: 50 55

receiving a new data packet which is formed to

a format using in the mobile communication system, the formed the data packet includes a time-stamp of first local sequence number; giving a time-stamp of second local sequence number corresponding to the received time-stamp of first local sequence number; sending back a acknowledgement data which includes an acknowledgement number and the given time-stamp of second local sequence number corresponding to the received time-stamp of first local sequence number.

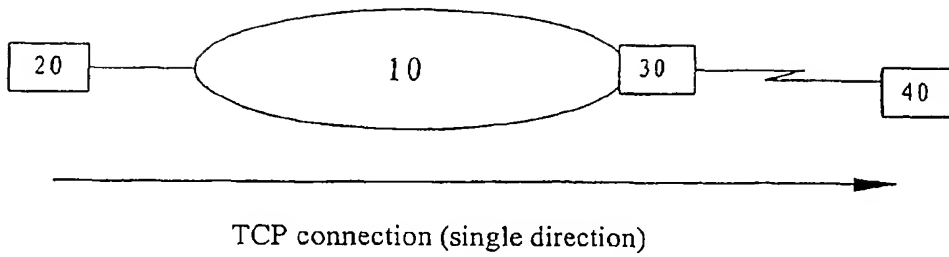


Figure 1

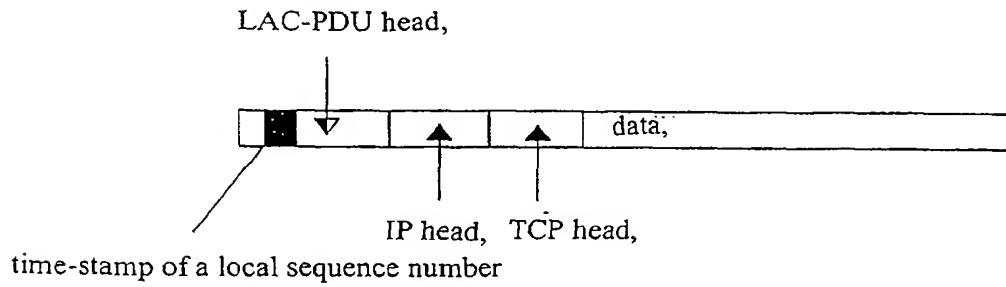


Figure 2

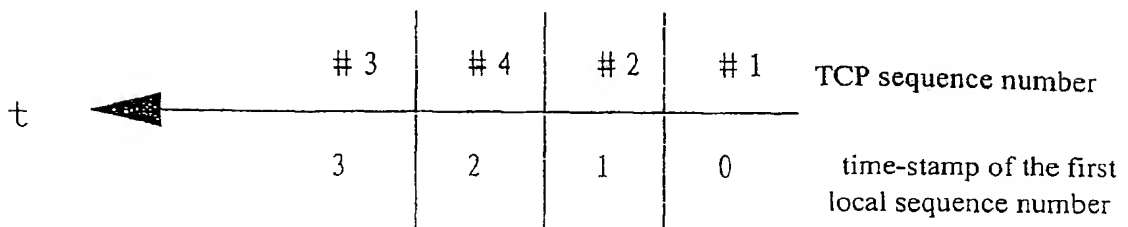


Figure 3

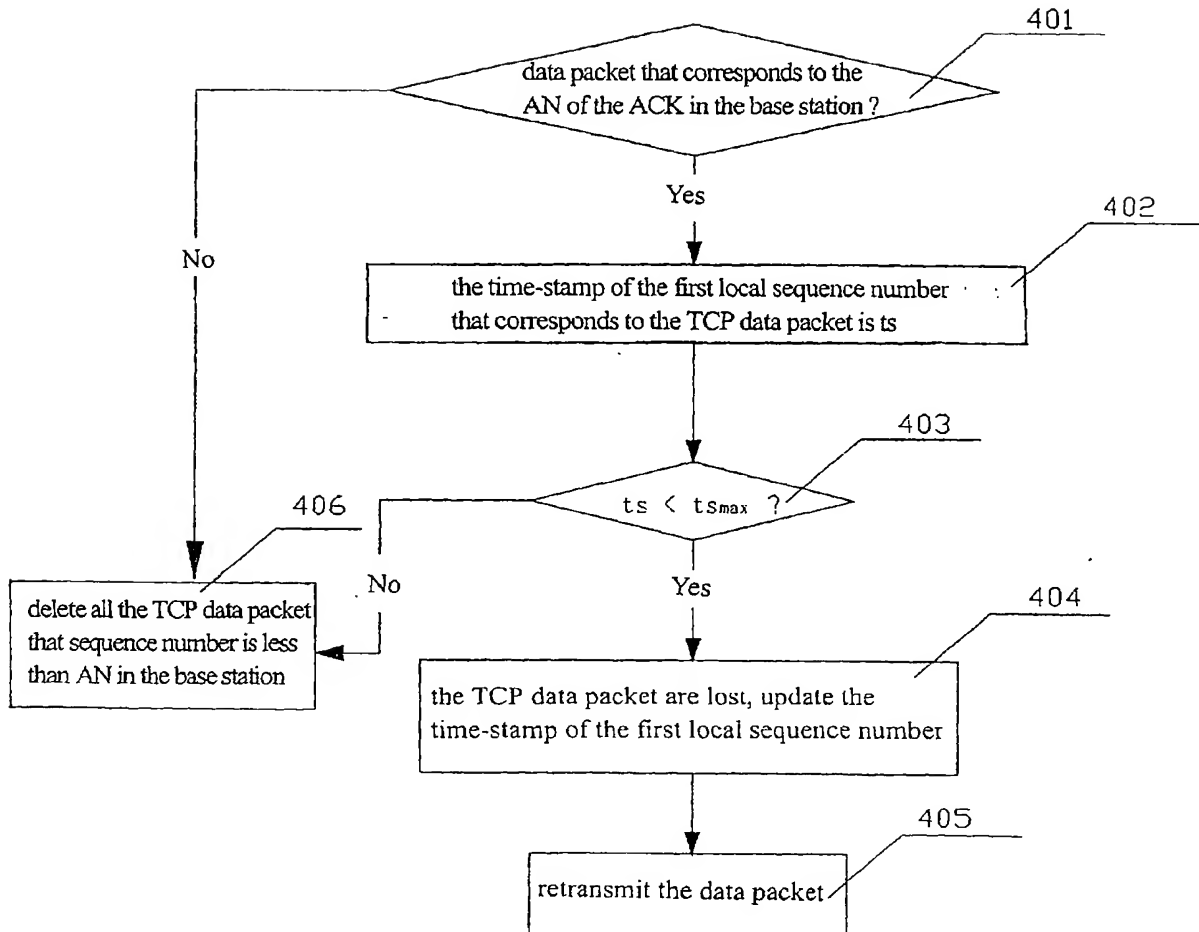
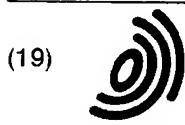


Figure 4:



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11) **EP 1 180 869 A3**

(12) **EUROPEAN PATENT APPLICATION**

(88) Date of publication A3:
03.12.2003 Bulletin 2003/49

(51) Int Cl.7: **H04L 1/18, H04L 29/06,
H04L 12/56**

(43) Date of publication A2:
20.02.2002 Bulletin 2002/08

(21) Application number: **01118870.3**

(22) Date of filing: **16.08.2001**

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE TR**
Designated Extension States:
AL LT LV MK RO SI

• **FUJITSU LIMITED**
Kawasaki-shi, Kanagawa 211-8588 (JP)

(72) Inventor: **Niu, Zhisheng**
Haidian District, Beijing 100084 (CN)

(30) Priority: **18.08.2000 CN 00123517**

(74) Representative: **HOFFMANN - EITLE**
Patent- und Rechtsanwälte
Arabellastrasse 4
81925 München (DE)

(71) Applicants:
• **TSINGHUA UNIVERSITY**
Beijing100084 (CN)

(54) **A TCP aware local retransmission scheme for unreliable transmission network**

(57) The present invention relates to a local retransmission scheme, which uses Transport Control Protocol (TCP) in an unreliable network. It provides reliable transmission for out-of-order TCP data packet in unreliable link. It recovers all non-congestion loss packets. It avoids incorrect adjustment of window size in TCP source end. It applies a TCP local retransmission scheme, which checks together link layer transfer se-

quence and TCP source delivery sequence. With inserting timestamp of local sequence number, which is in TCP data packet and TCP acknowledgement packet, together with acknowledgement number AN, it is defined whether a data packet is lost and retransmitted. Then, with explicit retransmission ERN feedback, a TCP source false action is avoided. Therefore the TCP performance of wireless network is greatly improved.

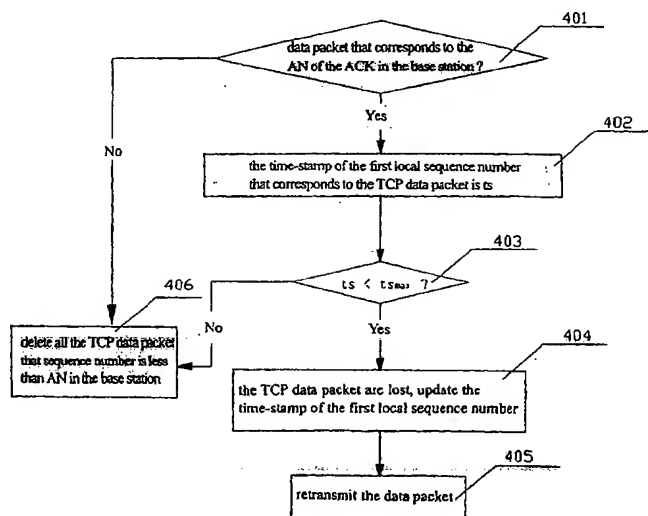


Figure 4:



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 11 8870

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
P,X	ZHU JING; NIU ZHISHENG : "A reliable TCP-aware link layer retransmission for wireless networks" PROCEEDINGS OF 16TH INTERNATIONAL CONFERENCE ON COMMUNICATION TECHNOLOGY (ICCT'00), vol. 1, 21 - 25 August 2000, pages 900-905, XP002190333 Beijing, China * the whole document *	1-15	H04L1/18 H04L29/06 H04L12/56
A	BALAKRISHNAN H ET AL: "A COMPARISON OF MECHANISMS FOR IMPROVING TCP PERFORMANCE OVER WIRELESS LINKS" IEEE / ACM TRANSACTIONS ON NETWORKING, IEEE INC. NEW YORK, US, vol. 5, no. 6, 1 December 1997 (1997-12-01), pages 756-769, XP000734405 ISSN: 1063-6692 * the whole document *	1-15	<div>TECHNICAL FIELDS SEARCHED (Int.Cl.7)</div> <div>H04L</div>
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
BERLIN		18 September 2003	Martínez Martínez, V
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

EPF FORM 1523 03.02 (P04C31)